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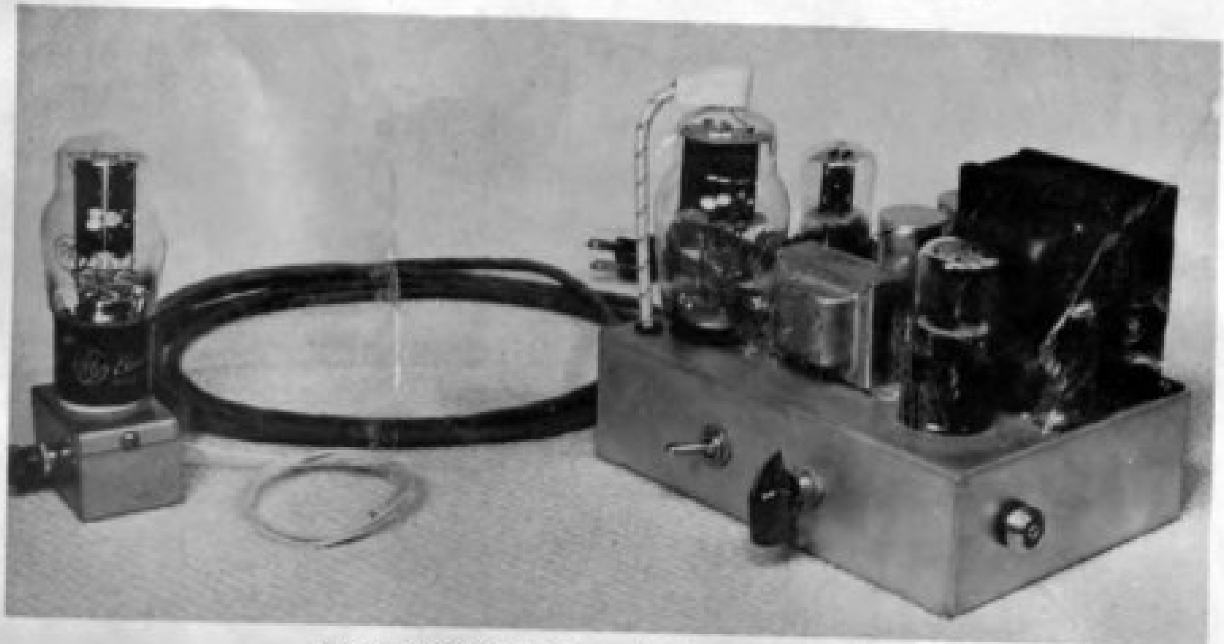
WITH

The "Rothman System" of Modulation



Model KW52 Modulator & Speech Amplifier,
1 KW Rating — Amateur Net.................$54.00

Mobile Modulator Model MO52 — 100 Watt
Rating — Amateur Net.................$12.50

Marmax Electronics

716 New York Avenue

ALAMOGORDO, NEW MEXICO

The Rothman System of Modulation

History and summary description

The Rothman System of Modulation was invented by Max I. Rothman* in January, 1961 for Marmac Electronics, Alamogordo, New Mexico. This system is a new method of achieving high efficiency amplitude modulation without the use of expensive and bulky high level modulation equipment. The system utilizes demodulated carrier feedback to control the angle of radio frequency flow of plate current in a pentode or tetrode RF amplifier tube in such a manner that screen modulation may be achieved without appreciable efficiency modulation; e.g., the angle of plate current flow is kept relatively constant throughout the modulation cycle. It is apparent from this that modulation is thereby achieved by control of the instantaneous tube impedance, and that any attendant efficiency modulation is caused only as a result of impedance variation rather than modulation of the current flow angle which is the greater factor. With proper choice of impedance values, efficiency modulation in the Rothman System is reduced to a secondary factor.

Theory of Operation

In the Rothman System, screen power for the radio frequency amplifier is obtained by rectifying a portion of the RF energy present in the tank circuit. It is thus evident that the RF tube used must have a favorable ratio of screen power requirement compared to rated plate power output. If this condition is met and proper feedback ratio is employed, the stage automatically adjusts its plate current versus screen voltage ratio for optimum efficiency during each portion of the modulation cycle. This effect is caused by the fact that the point in the screen characteristic at which plate efficiency starts to decrease is essentially coincident with the point at which a further increase in screen voltage produces a proportionately smaller increase in output power. Control of this automatic loading effect may be used as a means of varying the power input to the plate circuit of the radio frequency amplifier stage. In effecting this control, any convenient parameter may be chosen which initiates the desired instantaneous change in carrier level. At this point the regenerative feedback action of the system amplifies this change by a factor related to the screen grid transconductance of the tube. Figure 1 embodies a circuit diagram of an improved Rothman Modulation unit wherein screen feedback control is conveniently accomplished by use of voltage divider action between the screen impedance and that of a modulated control tube. This particular embodiment has been chosen for its simplicity, versatility and excellent stability. Other methods of control however, are entirely feasible; e.g., transformer coupling of control energy into any tube electrode. In Figure 1, controlled carrier operation is achieved by means of R1-C1 which charges to a grid bias level directly related to the modulating energy. Since this bias controls the average impedance of control tube V-1 and therefore the average ratio of screen feedback, it may be chosen to produce any desired controlled carrier characteristic. Constant carrier operation may be achieved by the insertion of a suitable cathode resistor and by-pass condenser in the control tube circuit. Any intermediate degree of controlled carrier action may be achieved by suitably relating R1-C1 with the cathode bias network.

Figure 2 embodies a Rothman Modulator circuit designed for mobile transmitter application and utilizes suitably smaller tubes. In this circuit, a cathode follower is utilized to provide the screen power. This is done in order to accomplish Rothman modulation feedback without consuming appreciable RF power. In general, it may be stated that with the circuitry illustrated in Figure 1, the RF amplifier tube must be chosen for relatively low plate impedance and small screen power requirement while the control tube similarly should be of low impedance in order that it may provide good control action at low screen voltage. It is important to note that since in the circuitry shown, no audio is impressed on the plate supply, the plate voltage used should be equal to the sum of the DC and AC components present in a high level modulated stage for a given tube. However, proper choice of low impedance tubes makes it entirely feasible to design Rothman Modulated transmitters which operate at conventional plate voltages. The 6BQ6 and 6BG6 are typical tubes which meet the above requirements and which will operate up to 30 megacycles and even higher with reduced plate efficiencies. In this respect Rothman Modulation does not differ from other systems with the exception that as plate efficiency

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*Electronic scientist, Holloman Air Force Base, New Mexico

drops due to marginal frequency operation the amount of control energy is proportionately lower. For this reason Rothman Modulation does not operate advantageously with frequency multiplying stages. As in all controlled carrier systems, power supply regulation is important when used with Rothman Modulation. However, advantage of the controlled carrier duty cycle may be had by the use of large output capacitance in the power supply as a storage tank to decrease instantaneous peak power requirements from the supply.

Charts and Illustrations:

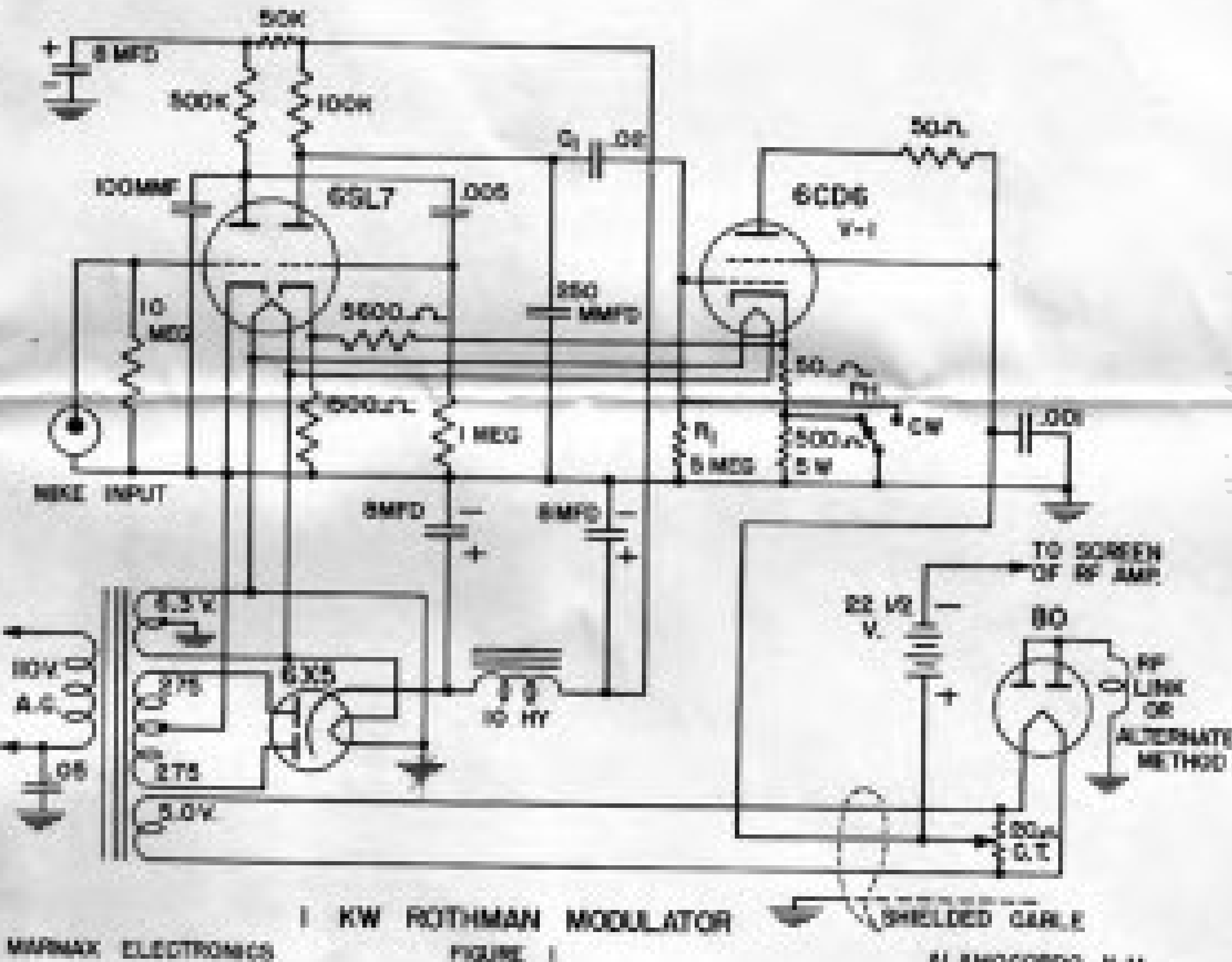
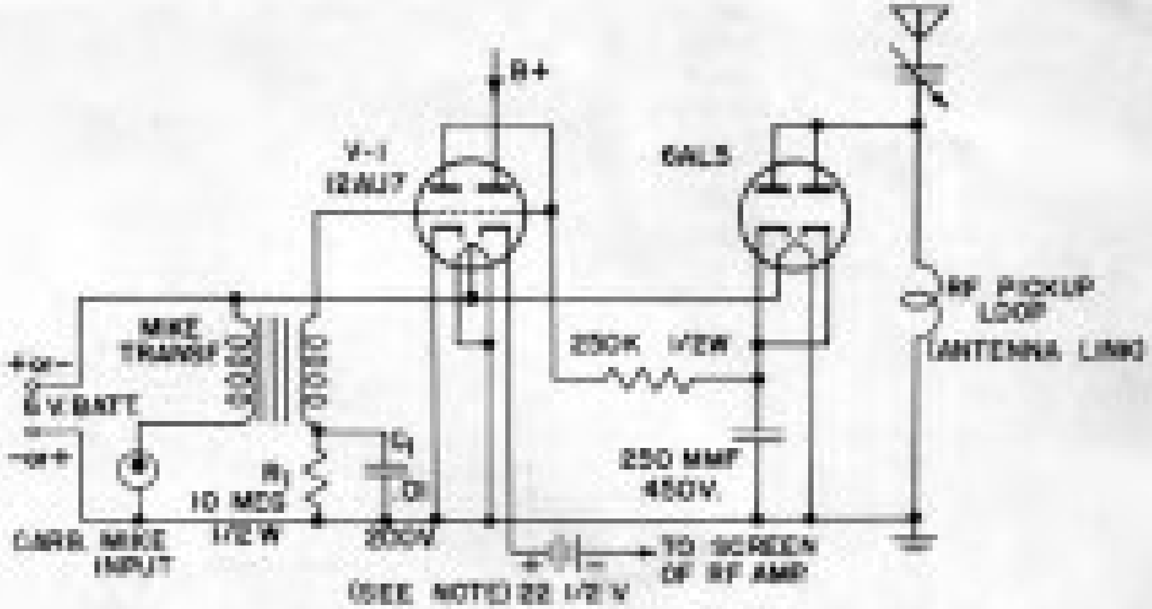


FIGURE 1: Rothman Modulator for fixed station operation. This circuit will modulate up to 1 KW with 100% safety factor.



I WATT TO 100 WATT ROTHMAN MODULATOR FOR MOBILE
FIGURE 2

FIGURE 2: This unit will modulate up to a plate input power of approximately 100 watts with relatively low battery drain. The 22½ volt screen bias battery required only with high plate impedance class C R. F. tubes to obtain 100% modulation.

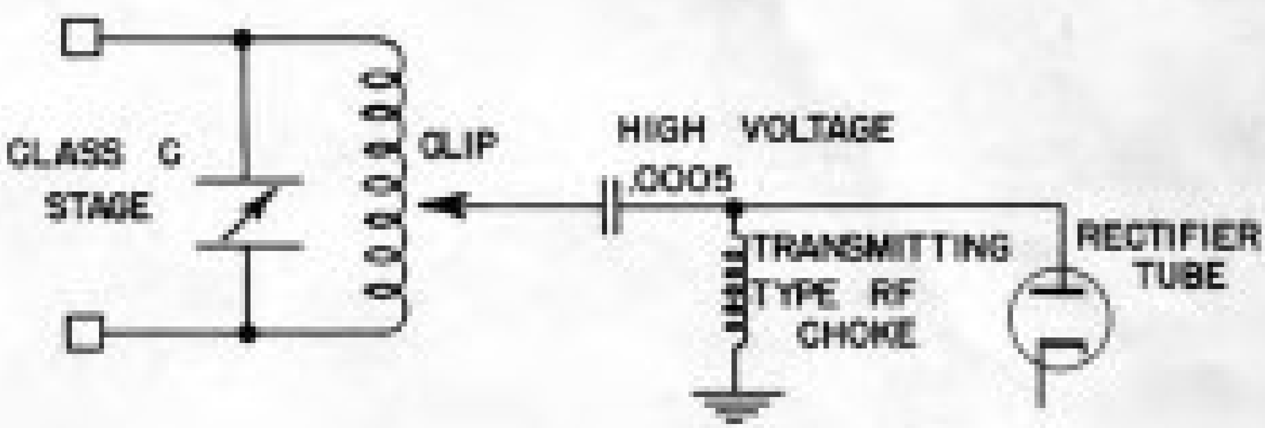


FIGURE 3: Alternate method of obtaining RF from plate tank.

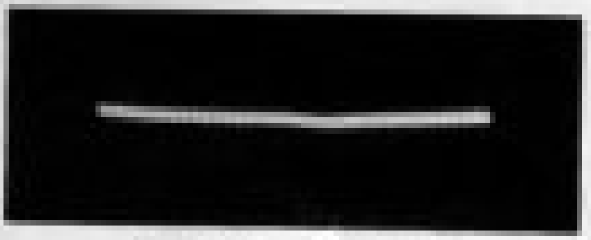


FIGURE 4: No carrier.

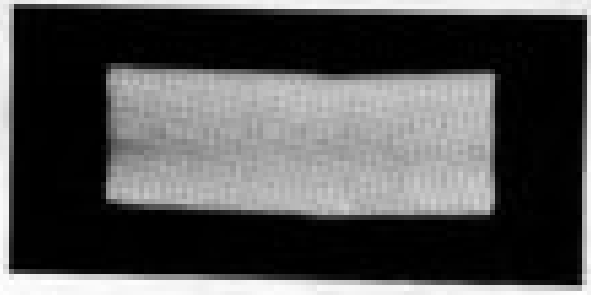


FIGURE 5: Carrier without modulation.

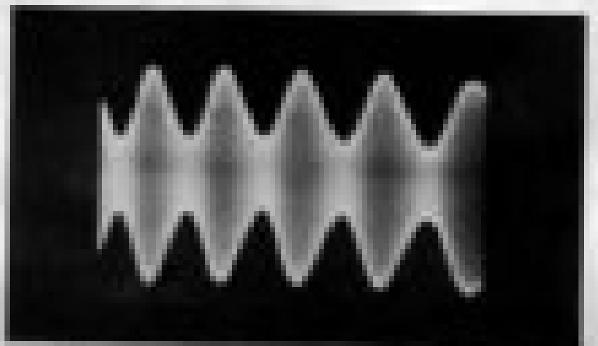


FIGURE 6: Undermodulated carrier.

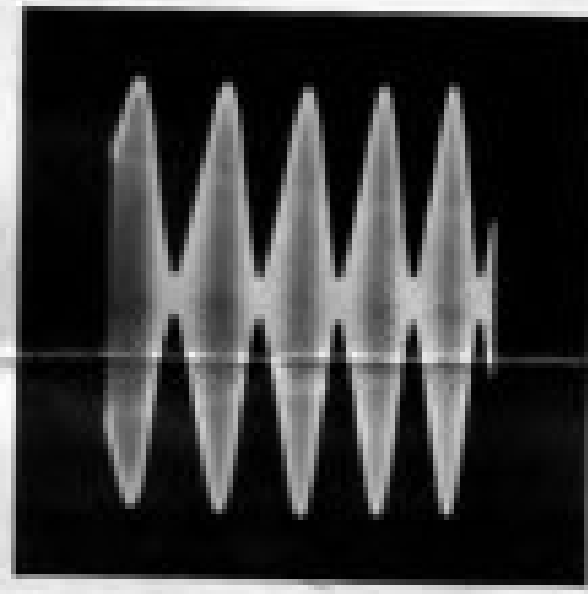


FIGURE 7: Fully modulated carrier.

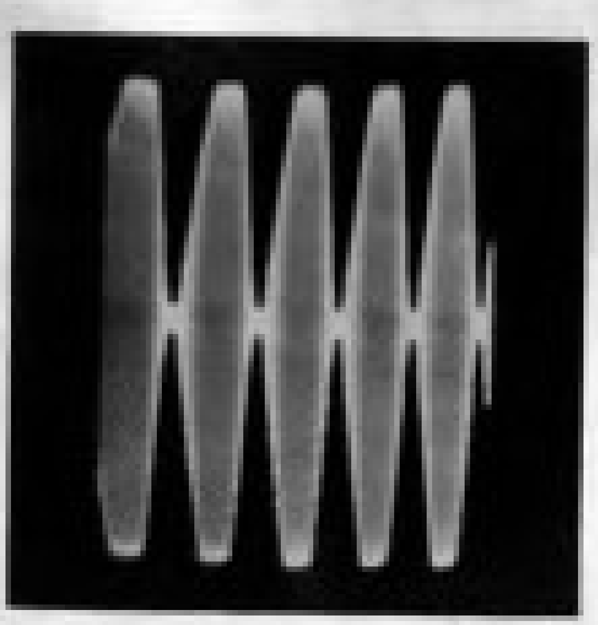


FIGURE 8: Overmodulated carrier.

Oscilloscope photographs taken from a transmitter modulated with the circuit of Figure 1. Modulation frequency 400 cycles.

Plate Efficiency Measurements:

The following data were taken for the modulation conditions of Figure 7: The transmitter used a pair of Eimac 4-250 A's in push-pull operating at 14 megacycles: The plate voltage was 5000 volts and plate current 200 milliamperes.

RF output power measurements were made with a thermocouple type RF ammeter connected in series with a 200 ohm non-inductive dummy load carefully matched to the output link of the transmitter with a total lead length of less than six inches in order to eliminate the possibility of standing wave error. With this arrangement, an output current reading of 2.3 amperes was recorded under 100% sine wave modulation conditions.

1. Input to the Rothman modulated class C stage at 100% modulation was 1000 watts D. C. power (5000 volts x 0.2 amperes) plus 500 watts A. C. power (Audio component).
2. Output from the same stage to a 200 ohm non-reactive dummy load was 2.3 R. F. amperes. This computes to (2.3) 2 x 200 or 1058 watts.
3. Percent efficiency of this stage (And overall conversion efficiency) was therefore 1058/1500 times 100 or 70.5%.
4. Average efficiency of high level modulated class C stages as quoted in Terman's Radio Engineering Handbook is 66 2/3%.
5. Average efficiency of class B modulators as quoted in the same reference is 55%.
6. Thus to obtain 500 watts of sine wave audio power to 100% modulate 1000 watts of D. C. input to a high level modulated class C stage it is necessary to supply 500 x 100/55 or 909 watts of D. C. power to the class B modulator.
7. Thus, in a high level modulated stage with a D. C. input power of 1000 watts and a class C efficiency of 66 2/3%, the output power will be 1500 watts (1000 watts D. C. plus 500 watts audio) times 0.66 2/3 or 1000 watts. However, the combined D. C. input power of the class C R. F. and the class B modulator stages is 1000 watts (Class C) plus 909 watts (Class B) or 1909 watts.
8. The overall plate conversion efficiency in percent of such a class C R. F. and class B modulator combination is therefore 1000/1909 times 100 or 52.4%.

Comparison of the two Systems is as follows:

Class C stage efficiency with Rothman modulation is 70.5%.

Overall conversion efficiency with Rothman modulation is 70.5%.

Class C efficiency with high level modulation is 66 2/3%.

Overall conversion efficiency with high level modulation is 52.4%.

Operation and Adjustment Procedure:

a. Plate voltage to class C stage must be adjusted to at least one and one-half times and preferably twice the manufacturer's rating for a high-level modulated stage.

b. The screen by-pass condenser of the class C stage should not exceed 250 mmfd for frequencies of 14 megacycles or above, 500 mmfd for frequencies between 3 and 14 megacycles, or .001 mfd for frequencies below 3 megacycles.

c. The Rothman Modulator should be used as the sole source of screen power.

d. Screen feedback under full modulation conditions should be adjusted to produce one-half the manufacturer's rated screen voltage for a high-level modulated stage. This measurement should be performed with a D.C. voltmeter possessing a sensitivity of at least 1000 ohms per volt.

e. Resonance adjustment should be made for maximum RF output current with the CW phone switch (figures 1 and 2) in the CW position. As opposed to conventional systems, the Rothman Modulated stage draws maximum plate current at resonance since no screen voltage is developed under off-resonance conditions. Care must be exercised not to exceed optimum screen feedback since this will in all cases decrease the plate efficiency of the modulated stage. Correct procedure is to start with insufficient coupling; e.g., one turn or less, and gradually increase coupling until the desired input power is obtained or until a decrease in antenna current is noted. Should this point be reached before desired plate input is obtained an increase in plate voltage is indicated.

f. Since the degree of output coupling to the RF load affects the amount of energy in the plate tank and therefore the screen feedback link, adjustment of output coupling and feedback coupling are interdependent.

g. In some tubes zero carrier level cannot be achieved with zero screen voltage. In such cases, 100% modulation may nevertheless be achieved by the addition of a negative bias battery in series with the screen lead from the modulator, figure 3. This bias requirement will usually not exceed 22-1/2 volts.

Advantages and Limitations of the System:

a. High efficiency modulation is achieved without the use of expensive and bulky high-level modulation equipment.

b. Screen power supplies are not required for the system.

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c. Protection from high off-resonance plate currents is achieved since screen power is generated only at resonance. Thus protective fixed grid bias is unnecessary and grid leak bias may be used exclusively.

d. Class A quality is easily achieved since straight resistance coupled stages are used throughout, and demodulated carrier feedback is utilized to overcome non-linearity of the screen characteristic.

e. Controlled carrier build-up is essentially instantaneous due to regenerative action, thereby preventing envelope distortion.

f. The system requires higher plate voltage at lower plate current than a conventional plate modulated stage.

g. The system is not advantageous when used with tubes which do not have suitably related screen power to output power ratings. This limitation however, is not serious since an adequate number of suitable tubes for all power levels are available.

h. Linear modulation may be accomplished at any frequency which is suitably related to the carrier frequency.

Conclusions:

The Rothman system of modulation is a simple, versatile and economical means of producing high-efficiency, and high fidelity amplitude modulation with a minimum of size and weight requirement.

While the system is ideally suited to communications applications it also possesses exceptional versatility in the video field wherein unusually high-frequency modulation components are encountered, e.g., in television transmitters which presently use control grid modulation, it is estimated that the use of Rothman modulation would enable a 75% increase of RF power output for a given plate power input.

Model KW52 is marketed complete with tubes, CW-phone switch, automatic gain control, fitting for crystal microphone input, 8 feet of connecting shielded cable and self contained power supply for 110 volt AC operation.

Model MO52 is complete with tubes, carbon microphone input transformer and all components mounted for plug-in to 6 prong socket.

If your dealer can not supply Rothman Modulators, write direct to factory.

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